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Proposal of compensatory technique for sustainable urban stormwater management: A case study in the municipality of Jaboatão dos Guararapes/PE

Proposta de técnica compensatória para manejo sustentável de águas pluviais urbanas: Estudo de caso no município de Jaboatão dos Guararapes/PE

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Abstract

The accelerated urban expansion of Brazilian cities, which occurred from the second half of the 20th century onward without proper oversight by public authorities, resulted in significant changes in the urban hydrological cycle. This type of transformation intensifies and exacerbates episodes of flooding and inundation events. In light of the above, this study aimed to propose a sustainable approach to urban stormwater management in an area vulnerable to flooding and waterlogging in the municipality of Jaboatão dos Guararapes, Pernambuco, through the implementation of a detention reservoirs as a compensatory technique. The sizing of the proposed system was carried out based on the excess surface runoff volume generated by the effect of urbanization, considering the difference between the total volumes produced under post- and pre-urbanization scenarios. The results indicated that, for a rainfall event lasting 15 minutes with a five years return period, 196.86 m^3 of precipitation will be retained in the microbasin. This finding demonstrates that the proposed technique can mitigate the impacts of hydrological disasters in the region. The implementation of this system could support public policies that encourage the adoption of compensatory techniques, particularly in areas characterized by intense urban densification.

Keywords:
Hydrological Disasters, Urban Expansion, Detention Reservoirs.

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Resumo

A acelerada expansão urbana das cidades brasileiras, ocorrida a partir da segunda metade do século XX sem o devido acompanhamento do Poder Público, resultou em significativas modificações no ciclo hidrológico urbano. Esse tipo de transformação intensifica e potencializa episódios de inundações e alagamentos. Diante do exposto, este estudo teve como objetivo propor o manejo sustentável das águas pluviais urbanas em uma área vulnerável a inundações e alagamentos no município de Jaboatão dos Guararapes, em Pernambuco, a partir da implantação de um reservatório de detenção como técnica compensatória. O dimensionamento do sistema proposto foi realizado com base no volume excedente de escoamento superficial causado pelo efeito da urbanização, considerando a diferença entre os volumes totais gerados pelos cenários pós e pré-urbanização. Os resultados indicaram que, em um evento chuvoso de 15 minutos de duração e com tempo de retorno de cinco anos, serão retidos 196,86 m³ de águas precipitadas na microbacia. Essa constatação demonstra que a técnica proposta pode mitigar os impactos de desastres hidrológicos na região, e a implementação desse sistema pode fundamentar políticas públicas que incentivem a adoção de técnicas compensatórias, principalmente em áreas de intenso adensamento urbano.

Palavras-chave:
Desastres Hidrológicos, Expansão Urbana, Reservatório de Detenção.

I. INTRODUCTION

The process of urbanization in Brazil occurred rapidly in major urban centers and was largely characterized by expansion without adequate oversight by public authorities, representing a direct consequence of industrial capitalism (Bezerra, 2022). This phenomenon has generated urban planning, economic, environmental, and social challenges, compromising both strategic planning and quality of life in urban areas (Nicolodelli; Ribeiro, 2023; Tsuji et al., 2023).

In this context, as the urban fabric expanded, natural surfaces underwent significant transformations, particularly due to the reduction of original vegetation cover and the increase in impervious surfaces, thereby decreasing the infiltration of precipitation into the soil and substantially increasing surface runoff (Tang et al., 2024). This type of intervention in the components of the hydrological cycle heightens vulnerability to flooding and urban waterlogging, especially in areas with obsolete and or obstructed drainage systems (Schorn; Vieira, 2023; Silva et al., 2023).

Flooding occurs primarily as a result of the overflow of water from natural water bodies, generally arising from the combination of meteorological and hydrological events (Alves et al., 2024). Urban waterlogging refers to the accumulation of water on streets and sidewalks due to the inadequacy of urban drainage systems (Pereira; Miranda, 2023). These types of hydrological disasters cause significant damage to communities, property, and the environment, forcing thousands of families to leave their homes and exposing their physical and mental health to multiple risks (Veenema et al., 2017; Paterson et al., 2018; Sholihah et al., 2020).

Compensatory techniques for stormwater management are increasingly recognized as environmentally sustainable solutions in urbanized areas. These methods, which integrate natural processes into urban planning, promote the infiltration and retention of precipitation. Techniques such as permeable pavements, green roofs, rain gardens, and detention reservoirs contribute to reducing surface runoff volumes, thereby decreasing the risk of flooding and urban waterlogging (Quin, 2020; Kim et al., 2024; Noleto; Rodrigues, 2024).

The implementation of compensatory techniques for urban stormwater management has been widely studied in several countries, including permeable pavements in Italy (Ciriminna et al., 2022), green roofs in Singapore (Lim et al., 2021), rain gardens in Ukraine (Kravchenko et al., 2024), infiltration trenches in Jordan (Abu-Zreig et al., 2020), and detention reservoirs in Slovenia (Glavan et al., 2020). At the national level, numerous studies have examined this practice across different regions of Brazil (Ribeiro; Nunes, 2020; Mendes; Andrade, 2021; Parra et al., 2021; Nunes et al., 2023; Vicente et al., 2023; Souza; Ohnuma Júnior, 2024).

Among the various compensatory techniques, detention reservoirs are effective systems for minimizing peak stormwater discharge in urban areas. They operate by temporarily storing rainwater and gradually releasing it, thereby reducing the impacts of flooding and urban waterlogging (Kempka et al., 2024). In addition to mitigating the impacts caused by flooding and waterlogging, these systems allow for the sedimentation of impurities, improving water quality (Souza et al., 2019).

By the end of the twentieth century, several Brazilian municipalities, including Jaboatão dos Guararapes, experienced a process of unplanned urban expansion without adequate support from public authorities, resulting in densely populated areas (Pessoa Neto et al., 2023a). The significant urban occupation process in the municipality, through both formal and informal settlements, led to the removal of vegetation, particularly riparian forests, contributing to substantial changes in the physical and natural environment and increasing the risk of flooding and urban waterlogging, especially during intense rainfall events.

This situation was evidenced by the rainfall recorded in the municipality of Jaboatão dos Guararapes on May 28, 2022, when one of the most severe climatic disasters ever documented in the region occurred, with an accumulated precipitation of 252.40 mm, corresponding to 90.54 percent of the monthly average (Agência Pernambucana de Águas e Clima, APAC, 2022). In addition to flooding and urban waterlogging, this extreme event triggered mass movements, resulting in more than 127 fatalities, approximately 4,000 displaced persons, and extensive material losses (Coutinho et al., 2024).

The implementation of detention reservoirs, when properly sized, can significantly reduce peak discharge and the impacts associated with urban waterlogging and flooding in densely occupied areas, such as those found in Jaboatão dos Guararapes. Accordingly, the present study aimed to propose a sustainable approach to urban stormwater management in an area vulnerable to flooding and waterlogging in the municipality of Jaboatão dos Guararapes, Pernambuco, through the implementation of a detention basin as a compensatory technique. The proposal considered the local physical and natural characteristics, the prevailing urbanization pattern, the identification of areas most susceptible to these processes, and the hydraulic sizing of the proposed basin.

II. LOCATION AND CHARACTERIZATION OF THE STUDY AREA

The municipality of Jaboatão dos Guararapes, the area under study, is located in the coastal zone of the state of Pernambuco and forms part of the Recife Metropolitan Region. It lies between the geographic coordinates 8° 2′ 48″ and 8° 14′ 31″ south latitude and 34° 54′ 23″ and 35° 6′ 54″ west longitude, as shown in Figure 1.

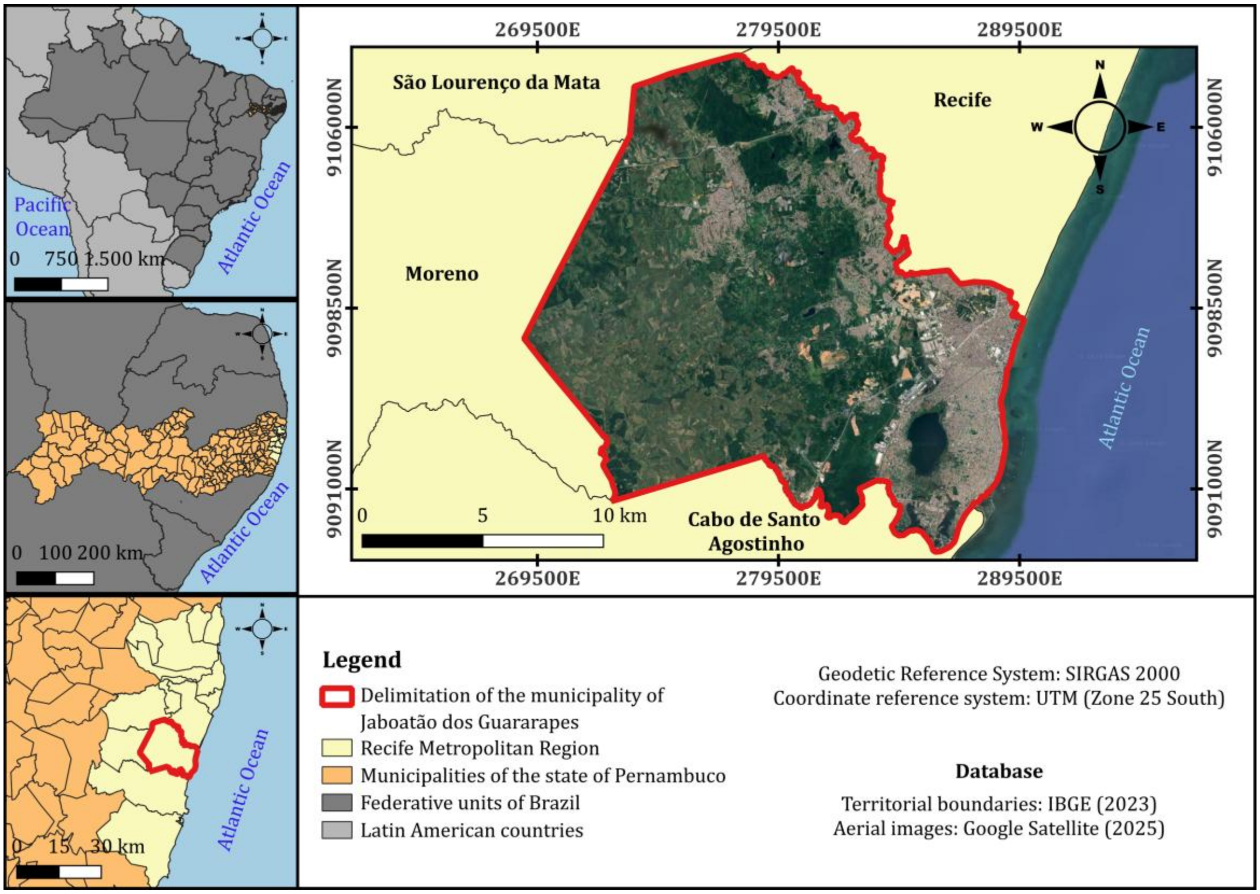

Figure 1 – Location of the municipality of Jaboatão dos Guararapes. (Prepared by the authors, 2025).

According to the Brazilian Institute of Geography and Statistics, IBGE, Jaboatão dos Guararapes covers an area of 258.70 km² (IBGE, 2025). The municipality is located 16.10 km from the capital of Pernambuco, Recife, and is primarily accessed via the BR 101, BR 232, BR 408, PE 007, and PE 008 highways. Jaboatão is the second most populous municipality in Pernambuco, with an estimated population of 644,037 inhabitants, of whom 99.28 percent reside in urban areas, resulting in a population density of 2,489.28 inhabitants per km² (IBGE, 2025).

The relief of the study area comprises three distinct geomorphological units: the lowered coastal plateau, formed on crystalline rocks and the Cabo Formation, characterized by hills and undulating terrain; the coastal plain, composed of Pleistocene and Holocene marine terraces, as well as fluvial terraces and tidal lowlands; and the coastal tablelands, consisting of sedimentary stretches of the Barreiras Formation and areas of Algodoais deposits (Ramos, 2019). The geological characteristics of the municipality reveal the presence of four distinct geological units: the crystalline rocks of the Pernambuco Alagoas Massif; the volcano sedimentary rocks of the Cabo sedimentary basin, corresponding to the Cabo Formation; the Tertiary sediments of the Barreiras and Algodoais formations; and the Quaternary sediments of the alluvial and coastal plains (Ramos, 2019).

With regard to pedology, according to the Brazilian Agricultural Research Corporation, EMBRAPA, Jaboatão dos Guararapes presents six soil classes: Red Yellow Argisol, Hydromorphic Ferrihumiluvic Spodosol, Haplic Gleysol, Yellow Latosol, Quartzarenic Neosol, Mangrove Soils, in addition to urbanized areas (EMBRAPA, 2018). The original vegetation of the region consisted of species typical of humid tropical environments, including Tropical Forest, Restinga Ombrophilous Forest, and Mangrove vegetation (Coutinho et al., 2024). In terms of land use, rural areas are predominantly occupied by family farming and sugarcane monoculture, whereas industrial and service activities prevail in urban areas.

Regarding climatology, according to the Köppen Geiger classification, the municipality presents an As' climate type, defined as Tropical with winter rainfall. Easterly Wave Disturbances, together with sea breezes, exert a significant influence on precipitation volumes during the rainy season, which occurs between May and August (Wanderley et al., 2021). The dry season is characterized by a reduction in monthly rainfall totals and takes place between September and November, while the months from December to April correspond to a transitional phase between the two distinct climatic periods (Silva; Duarte, 2023). The region exhibits average monthly precipitation values ranging from 312 mm, maximum, to 29 mm, minimum, as shown in Figure 2, with an annual average of 1,754.84 mm (Pessoa Neto et al., 2022). The highest monthly precipitation typically occurs in June during the winter period, although it may be exceeded at other times of the year due to extreme rainfall events.

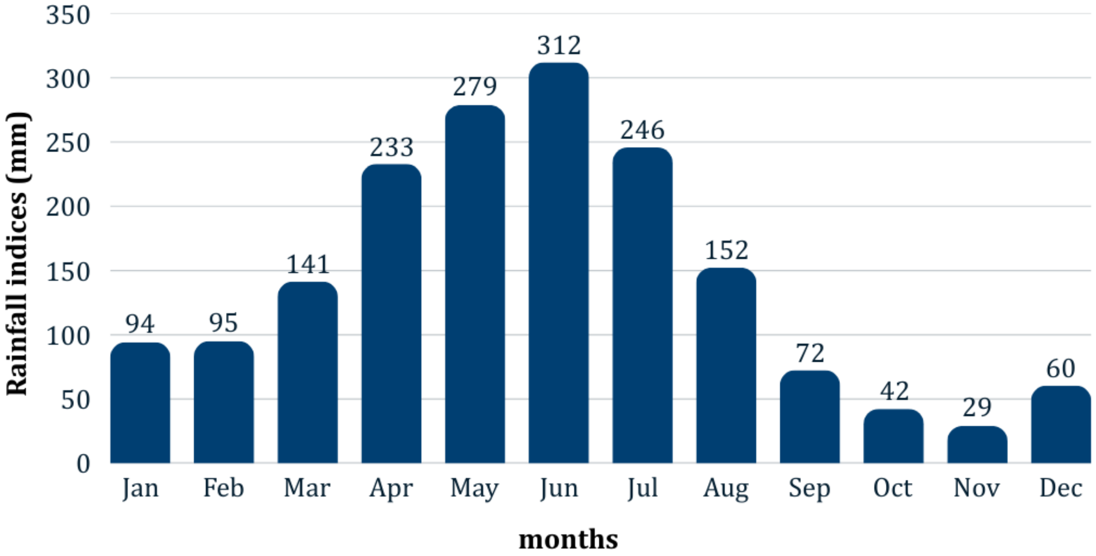

Figure 2 – Monthly average rainfall in the municipality of Jaboatão dos Guararapes for the period from 2004 to 2021. (Adapted from Pessoa Neto et al., 2022).

With regard to hydrography, the municipality is situated within the watersheds of the Jaboatão, Pirapama, and Tejipió rivers, which together comprise Planning Unit 04, designated as Metropolitan South (Secretaria de Infraestrutura e Recursos Hídricos de Pernambuco, SEINFRA, 2022). The Jaboatão River basin, which is the most relevant to the study area, encompasses two major rivers in Pernambuco: the Jaboatão and the Duas Unas. Within this basin, the Duas Unas Dam stands out, whose primary purpose is to supply part of the Recife Metropolitan Region, providing one of the largest water discharges conveyed to the area, corresponding to 1,000 L/s (Pessoa Neto et al., 2023b).

The physical and natural characteristics of the municipality, combined with its high level of urbanization, make Jaboatão dos Guararapes highly susceptible to flooding and urban waterlogging across much of its territory. Among the most vulnerable areas, the Barra de Jangada neighborhood is particularly noteworthy, as evidenced by the records presented in Figure 3. According to data from the National Registry of Addresses for Statistical Purposes, CNEFE, of the 338,688 properties registered in the municipality of Jaboatão dos Guararapes, 82,785 are prone to flooding (CNEFE, 2022). In the Barra de Jangada neighborhood, this condition is especially critical due to its location in a predominantly flat area adjacent to the outlet of the Jaboatão River and Olho D'Água Lagoon, and because it is intersected by the Olho D'Água Canal.

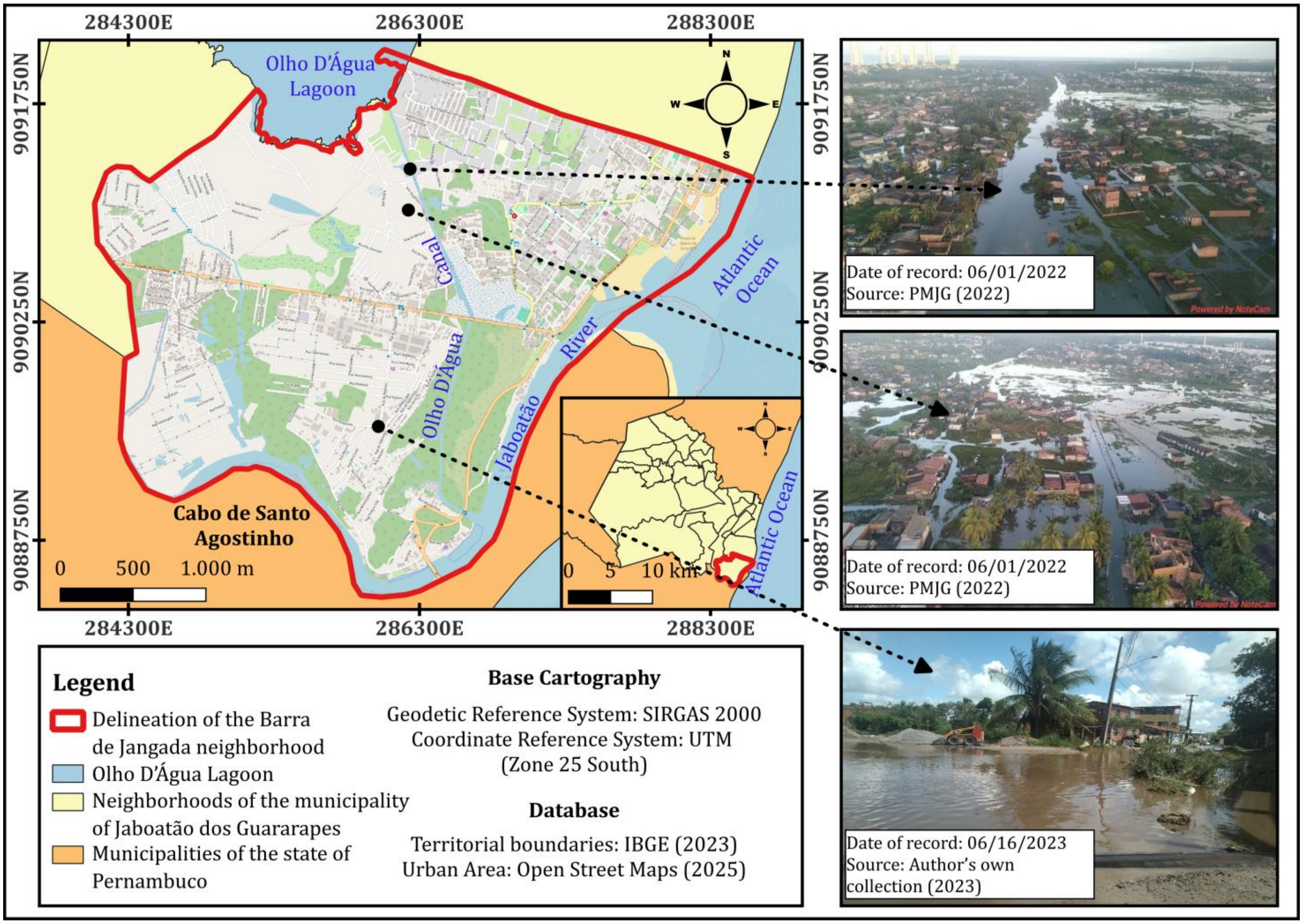

Figure 3 – Location of the Barra de Jangada neighborhood in the municipality of Jaboatão dos Guararapes and photographic records of flooding and urban waterlogging events that occurred in the area. (Prepared by the authors, 2025).

In addition to the aforementioned physical and natural characteristics, between 2002 and 2014 the Barra de Jangada neighborhood experienced significant urban expansion, driven by a new phase of growth of the Suape Industrial and Port Complex, resulting in the installation of several residential, commercial, and hotel developments in the area (Santos et al., 2024). Accordingly, detention reservoirs were selected as the compensatory technique due to their effectiveness in controlling peak discharge and their suitability to the physical and natural conditions as well as the urbanization pattern of the study area.

III. MATERIALS AND METHODS

Collection, Processing, and Analysis of Spatial Data for the Delineation of the Contributing Micro-Watershed and the Development of Pre- and Post-Urbanization Scenarios

Following the selection of the site for the implementation of the proposed detention basin, the delineation of a contributing micro-watershed was carried out in order to define the study area. For this purpose, Digital Elevation Models (DEMs) in raster format, with a spatial resolution of 0.10 meters, were acquired by the Municipality of Jaboatão dos Guararapes from airborne Light Detection and Ranging (LiDAR) surveys.

To delineate the contributing micro-watershed in QGIS (version 3.34.9), the DEMs were mosaicked and spurious pixels were removed, resulting in a Hydrologically Consistent Digital Elevation Model (HCDEM). Subsequently, after identifying the control section, the contributing watershed was defined.

Following this stage, the sizing of the detention basin considered both pre- and post-urbanization scenarios in order to compare the increase in runoff volume within the watershed resulting from soil imperviousness. For the spatial representation of these scenarios, elements of the municipal base cartography were initially obtained, including neighborhood boundaries, road network, parcels, and blocks, provided by the Municipality in vector shapefile format.

Additionally, for the composition of the pre-urbanization scenario, aerial images dated 1974 were provided by the Pernambuco State Agency for Planning and Research (CONDEPE/FIDEM). These images, derived from an aerophotogrammetric survey and available in JPG format, were georeferenced based on the indicated coordinates and mosaicked to generate a single image. For the 2025 scenario, representing post-urbanization conditions, aerial images obtained from Google Satellite, available through the QuickMapServices plugin in QGIS, were used.

Comparative analyses and visual interpretations were conducted by examining the transformations resulting from the evolution of urbanization in the study area. Based on these observations, thematic land use and land cover maps were produced for the years 1974 and 2025. To delineate the targets under study, a vector layer in shapefile format was created, consisting of polygons representing each identified land use and land cover class. After defining the polygons, the corresponding areas were calculated, enabling the analysis of changes within each category across the study area. All spatial data used in this study were processed in QGIS

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(version 3.34.9) using UTM coordinates (Zone 25 South) within the Geocentric Reference System for the Americas (SIRGAS 2000).

Sizing of the Detention Basin

To carry out the sizing of the compensatory technique, it was necessary to construct hydrographs representing the function Q(t), which describes water discharge, Q, as a function of time, t, for both pre- and post-urbanization scenarios. Since the total volume of water discharged over a time interval $[t_0, t_1]$ can be obtained by integrating the hydrograph function, as presented in Equation 1.

$$V = \int_{t_0}^{t_1} Q(t)\, dt \tag{1}$$

Where:

- V is the total volume of water discharged over the time interval $[t_0, t_1]$,

- t_0 is the initial time of the interval considered,

- t_1 is the final time of the interval considered,

- Q(t) is the hydrograph function, which describes water discharge as a function of time;

- dt is the infinitesimal time increment.

Thus, the excess water volume resulting from urbanization was determined by calculating the difference between the total volumes of the post-urbanization and pre-urbanization scenarios, as expressed in Equation 2.

$$V_{excedente} = \int_{t_0}^{t_1} (Q_{pós}(t) \; - \; Q_{pré}(t))\, dt \tag{2}$$

Where:

- $V_{excedente}$ is the total excess volume of water discharged over the time interval considered [t0, t1],

- t_0 is the initial time of the interval considered,

- t1 is the final time of the interval considered,

- $Q_{pós}(t)$ is the hydrograph function that describes water discharge as a function of time under the post-urbanization scenario,

- $Q_{pré}(t)$ is the hydrograph function that describes water discharge as a function of time under the pre-urbanization scenario,

- dt is the infinitesimal time increment.

Therefore, the difference between the two hydrographs, Q_post(t) and Q_pre(t), when integrated over time, provides the excess stormwater volume, reflecting the impact of urbanization on stormwater runoff in the region. The procedure described can be summarized in Figure 4.

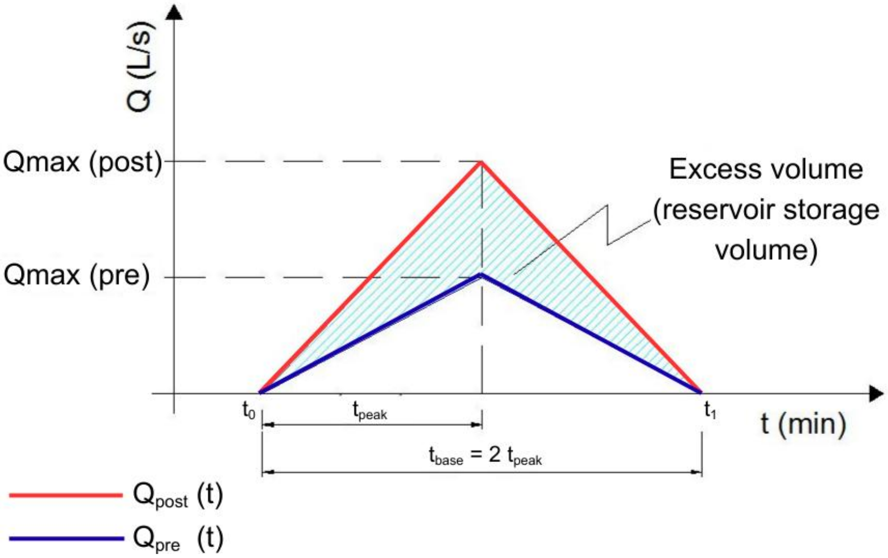

Figure 4 – Graphical representation of the hydrograph functions describing water discharge as a function of time under the pre- and post-urbanization scenarios, highlighting the excess water volume resulting from urbanization. (Prepared by the authors, 2025).

The time to peak (t_{peak}) and the base time (t_{base}) were defined, respectively, as the moment at which water discharge reaches its maximum value following a precipitation event and the time interval between the onset of rainfall and the return of discharge to its pre-event level after the peak has occurred.

Although urbanization alters runoff behavior, resulting in differences in peak and base times between pre- and post-urbanization scenarios, in this study these parameters were assumed to be coincident in both cases. This convention is commonly adopted for calculation purposes in micro-watersheds, particularly when a practical approach is employed. The use of such simplifications is a well-established practice in reduced drainage models or when approximations are required for the sizing of runoff control systems, such as detention reservoirs (Guerzoni Filho, 2014; Benini; Mendiondo, 2015; Souza, 2018; Lemos, 2021; Penner et al., 2021).

Peak discharge was determined using the Rational Method, as presented in Equation 3. This model, widely applied in small watersheds, establishes a relationship between the runoff coefficient, rainfall intensity, and the watershed area (Diogo; Carmo, 2019).

$$Q_{máx} = 2{,}78 \times C \times I \times A \tag{3}$$

Where:

- $Q_{máx}$ is the design peak discharge (L/s),
- C is the runoff coefficient (dimensionless)),
- I is the rainfall intensity (mm/h),
- A is the contributing area (ha).

The area of the micro-watershed was automatically calculated in QGIS, resulting in a total area of 2.62 hectares. To determine rainfall intensity, the intensity–duration–frequency (IDF) equation specific to the municipality of Jaboatão dos Guararapes (Equation 4) was applied. This equation was developed by the Geological Survey of Brazil (CPRM) and is presented in the Brazilian Rainfall Atlas (CPRM, 2014). It was derived from historical precipitation data collected between 1968 and 2007, comprising a 40-year time series.

$$I = \frac{1423{,}97 \times Tr^{0{,}1124}}{(t+21)^{0{,}7721}} \tag{4}$$

Where:

- I is the rainfall intensity (mm/h);
- T_r is the return period (years);
- t is the duration of the rainfall event (minutes).

Because the proposed system involves a microdrainage intervention and the implementation site is located in an area with predominantly residential land use, a five-year return period and a 15-minute rainfall event duration were adopted, values commonly used for this type of application (Melo et al., 2014).

The runoff coefficient, a dimensionless parameter representing the fraction of total precipitation that is converted into surface runoff, was calculated as the ratio between effective precipitation and total accumulated precipitation, as expressed in Equation 5).

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$$C = \frac{P_{ef}}{P} \tag{5}$$

Where:

- C is the runoff coefficient (dimensionless),
- P_{ef} is the effective precipitation (mm) over the duration of the event,
- P s the total accumulated precipitation (mm) over the duration of the event.

Total accumulated precipitation was defined as the product of rainfall intensity and event duration, as expressed in Equation 6. For this study, effective precipitation was estimated using the SCS (Soil Conservation Service) method, as shown in Equation 7. This model is based on the Curve Number (CN) parameter, which represents the runoff potential and is influenced by the hydrological soil classification, antecedent moisture conditions, and land cover (Schwab et al., 1993; Porto, 1995).

$$P = \frac{I \times t}{60} \tag{6}$$

Where:

- P is the total accumulated precipitation (mm);
- I is the rainfall intensity (mm/h);
- t is the duration of the rainfall event (minutes).

$$P_{ef} = \begin{cases} \frac{(P - 0{,}2 \times S)^2}{P + 0{,}8 \times S}, se\ P > 0{,}2 \times S \\ 0, se\ P < 0{,}2 \times S \end{cases} \tag{7}$$

Where:

- P_{ef} is the effective precipitation (mm) over the duration of the event,
- s the total accumulated precipitation (mm) over the duration of the event,
- S is the potential soil retention (dimensionless).

The potential soil retention parameter refers to the soil's capacity to store water and was determined using the model represented by Equation 8. The calculation of the Curve Number began with the identification of the soil type in the region and its corresponding hydrological soil classification, as shown in Table 1. To accomplish this, the hydrological classification of soil types within the study area was spatially represented using a vector file in shapefile format obtained from the Metadata Catalog of the National Water and Basic Sanitation Agency, ANA, at a scale of 1:100,000 (ANA, 2017).

$$S = \frac{25400}{CN} - 254 \tag{8}$$

Where:

- S is the potential soil retention (dimensionless),

- CN is the *Curve Number* (adimensional).

Table 1– Hydrological soil classification.

Group	Description
A	Soils with low surface runoff and high infiltration capacity, such as deep sandy soils with less than 8 percent clay content. There are no rock layers or clayey horizons within 1 meter of depth.
B	Soils with moderate infiltration, such as shallow sandy soils with less than 15 percent clay content. There are no rock layers or clayey horizons within 1.5 meters of depth, although a denser layer may occur at greater depths. These soils exhibit high permeability.
C	Soils with low infiltration capacity, mainly due to the presence of layers that restrict water movement. These are loamy soils with 20 to 30 percent clay content and no impermeable layers or rock within 1.2 meters of depth. These soils tend to generate above average surface runoff.
D	Soils that produce high surface runoff and have low infiltration capacity, such as expansive clays or shallow soils with impermeable layers near the surface. They contain 30 to 40 percent clay and present a dense layer at approximately 50 cm depth

Adapted from Schwab et al. (1993), Porto (1995), and Calzavara and Fernandez (2015).

Subsequently, with regard to antecedent moisture conditions (Table 2), Condition II was adopted, as it represents the average soil moisture condition during the wet season. Finally, the Curve Number was determined based on the hydrological soil classification and the land use and land cover characteristics (Table 03).

Table 2 – Soil Condition in relation to antecedent moisture.

Condition	Description
I	Dry soils: rainfall over the previous five days did not exceed 15 mm.
II	Average condition during the wet season: rainfall over the previous five days totaled between 15 and 40 mm.
III	Wet soil, close to saturation: rainfall over the previous five days exceeded 40 mm, and meteorological conditions were unfavorable to high evaporation rates.

Adapted from Schwab et al. (1993) and Porto (1995).

Table 3 – Curve Number values as a function of land cover and hydrological soil group (antecedent moisture condition II).

Land use type / treatment / hydrological conditions			Hydrological group			
			A	B	C	D
Residential land use						
	Average lot size	% Impervious surface				
	Up to 500m^2	65	77	85	90	92
	1.000m^2	38	61	75	83	87
	1.500m^2	30	57	72	81	86
Parking areas, pavements, and rooftops			98	98	98	98
Streets and roads:						
	Paved, with curbs and drainage		98	98	98	98
	Gravel		76	85	89	91
	Unpaved		72	82	87	89
Commercial areas (85% impervious cover)			89	92	94	93
Industrial districts (72% impervious cover)			81	88	91	93
Open spaces, parks, and gardens:						
Good condition, grass cover greater than 75%			39	61	74	80
Fair condition, grass cover greater than 50%			49	69	79	84
Land prepared for planting, bare soil:						
Straight-row planting			77	86	91	94
Row crops:						
	Straight row	Poor condition	72	81	88	91
		Good condition	67	78	85	89
	Contour farming	Poor condition	70	79	84	88
		Good condition	65	75	82	86
Grain crops:						
	Straight row	Poor condition	65	76	84	88
		Good condition	63	75	83	87
	Contour farming	Poor condition	63	74	82	85
		Good condition	61	73	81	84
Pasture:						
	Straight row	Poor condition	68	79	86	89
		Fair condition	49	69	79	84
		Good condition	39	61	74	80
	Contour farming	Poor condition	47	67	81	88
		Fair condition	25	59	75	83
		Good condition	06	35	70	79
Fields:		Good condition	30	58	71	78

Land use type / treatment / hydrological conditions		Hydrological group			
		A	B	C	D
Forests:	Poor condition	45	66	77	83
	Fair condition	25	55	70	77
	Good condition	36	60	73	79

Adapted from Schwab et al. (1993) and Porto (1995).

Accordingly, the thematic maps corresponding to the pre- and post-urbanization scenarios were considered. In the post-urbanization scenario, in which multiple land use and land cover types were identified, a weighted Curve Number was applied, obtained by summing the products of the Curve Number assigned to each class and its respective proportional area.

IV. RESULTS AND DISCUSSION

Following the delineation of the study area on the aerial images, a thematic map was produced, as shown in Figure 5, highlighting the comparison between the analyzed region under pre-urbanization conditions in 1974 and post-urbanization conditions in 2025. This area, selected for the implementation of the detention basin as a compensatory technique, consists of a micro-watershed located in the Barra de Jangada neighborhood and has its control section at the Olho D'Água Canal.

As observed in the pre-urbanization scenario, in 1974 the study area exhibited no anthropogenic interventions. This is evidenced by the predominance of natural vegetation and the presence of water associated with natural drainage networks in the vicinity of the canal. This characterization suggests that, during that period, the area could be considered preserved (Silva, 2010).

In the post-urbanization scenario, in 2025, anthropogenic areas increased considerably within the region. This process is primarily associated with the construction of the access road to the Wilson Campos Bridge, inaugurated in 2010, which facilitates access to the Suape complex and reduced the distance between it and the Recife Metropolitan Region by 40 km (Silva, 2013). Furthermore, during this period, intense building densification was observed in the Barra de Jangada neighborhood, resulting from the coastal urban expansion dynamic that had already consolidated in Recife and in other coastal neighborhoods of Jaboatão dos Guararapes (Costa, 2019).

For the sizing of the detention basin, it was initially necessary to determine a Curve Number for each scenario. Accordingly, the respective land use and land cover classes in the region were identified, as shown in Figure 6.

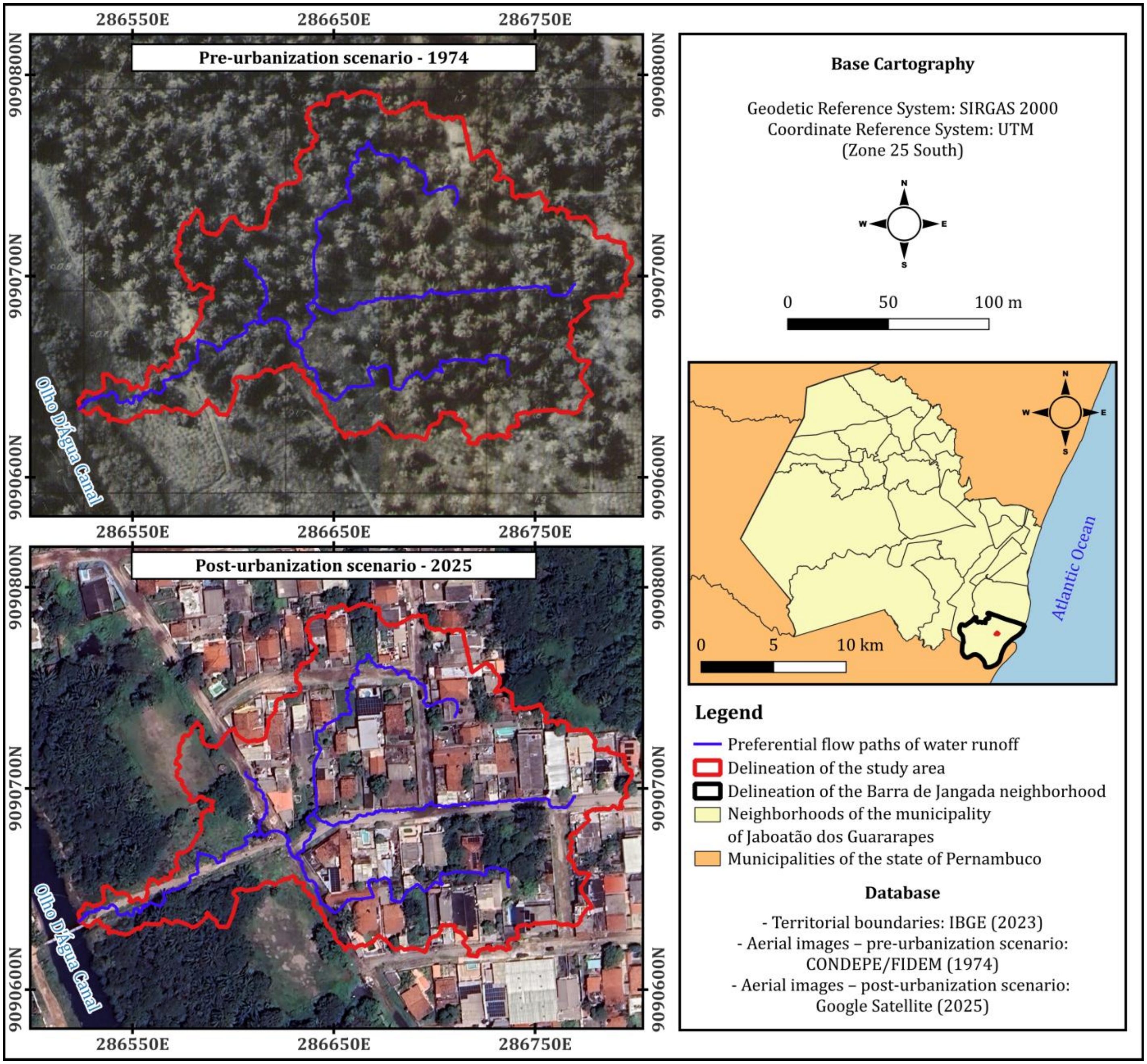
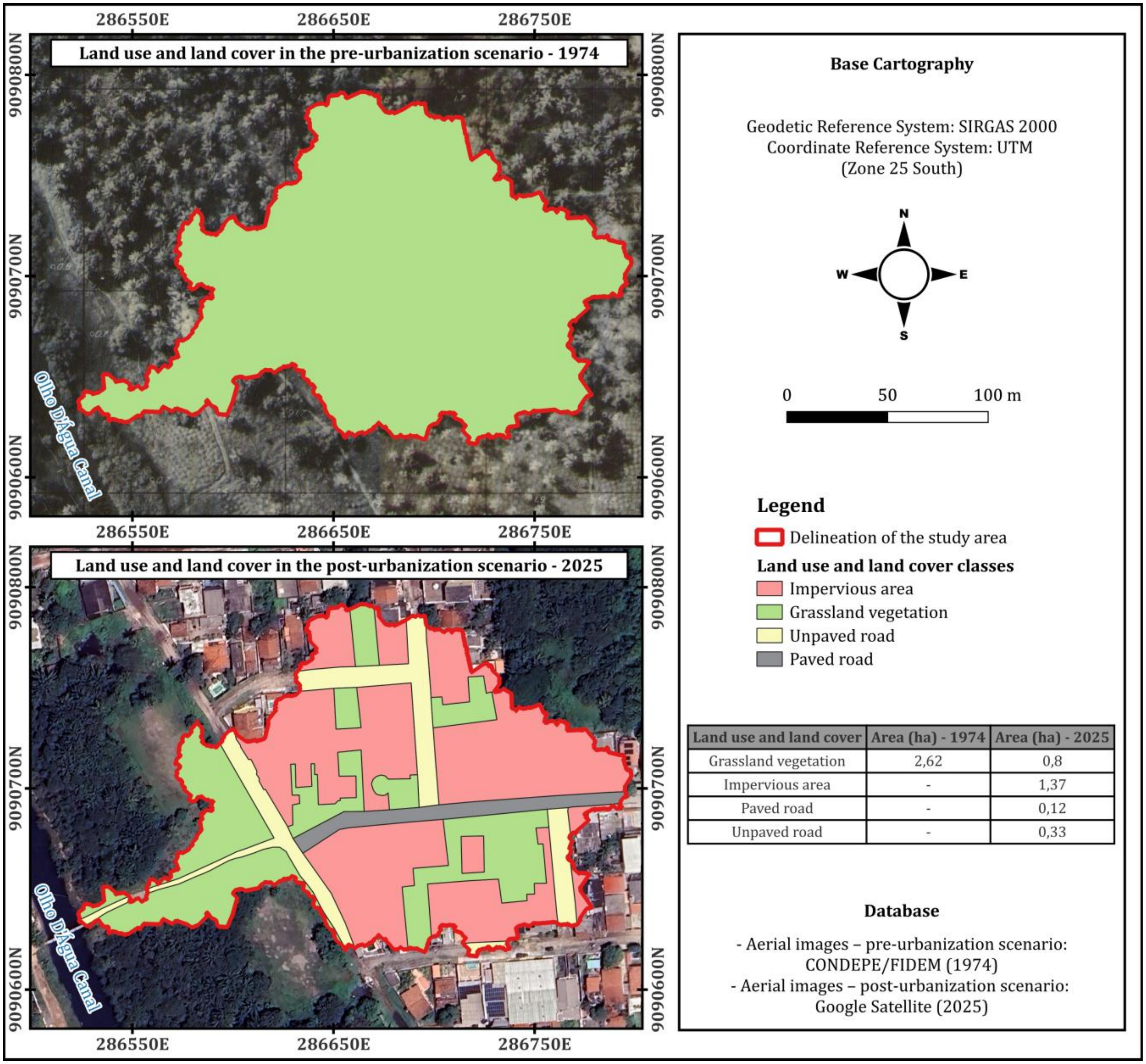


Figure 5 – Spatiotemporal evolution of urbanization dynamics between 1974 and 2025 in the study area. (Prepared by the authors, 2025).



Land use and land cover	Area (ha) - 1974	Area (ha) - 2025
Grassland vegetation	2,62	0,8
Impervious area	-	1,37
Paved road	-	0,12
Unpaved road	-	0,33

Figure 6 – Land use and land cover of the study area under pre- and post-urbanization scenarios. (Prepared by the authors, 2025).

Regarding the variation in land use and land cover classes within the study area, it was observed that, under pre-urbanization conditions, grassland vegetation predominated, particularly riparian forest and low herbaceous cover, totaling 2.62 ha and representing the entirety of the area.

In the post-urbanization scenario, a significant reduction in vegetated area was identified, decreasing to 0.80 ha, while classes associated with anthropogenic intervention became predominant. These were represented by impervious surfaces, including buildings, 1.37 ha, and access roads, both paved, 0.12 ha, and unpaved, 0.33 ha, resulting from landfilling and vegetation removal in the region.

In order to proceed with the calculation of the Curve Number, it was also necessary to identify the soil type present in the study area. According to the mapping shown in Figure 7, the soil corresponds to a Ferrihumiluvic Spodosol. This soil type belongs to hydrological soil group C under the SCS classification system (Almeida Neto, 2019). With the definition of land use and land cover classes and the hydrological soil classification, it was possible to determine the Curve Number for each scenario, as presented in Table 4.

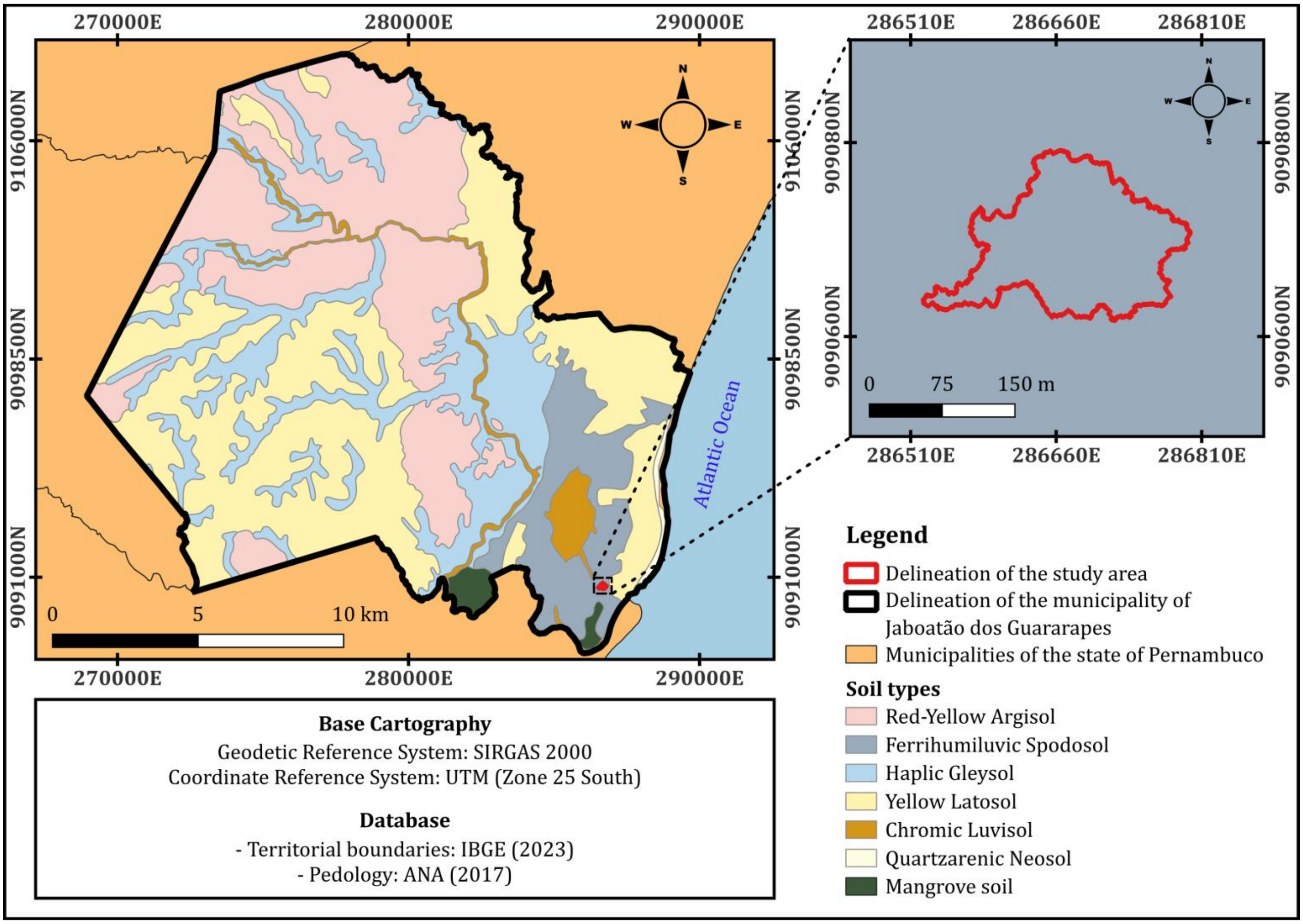


Figure 7 – Pedological map of the municipality of Jaboatão dos Guararapes, highlighting the identification of the soil type within the study area. (Prepared by the authors, 2025).

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Table 4 – Curve Number calculation for the study area under the pre- and post-urbanization scenarios.

Land use and land cover class	Pre-urbanization scenario			Post-urbanization scenario		
	CN	Area (ha)	Unit rate	CN	Area (ha)	Unit rate
Paved parking areas and rooftops	-	-	-	98	1.37	0.52
Paved streets and roads	-	-	-	98	0.12	0.05
Unpaved streets and roads	-	-	-	87	0.33	0.13
Fields in good condition	71	2.62	1	71	0.80	0.30
Weighted Curve Number		71			88.47	

Prepared by the authors, based on Schwab et al. (1993) and Porto (1995).

The analysis of the data presented in Table 5 reveals a significant impact of urbanization on surface runoff within the study area. When comparing the pre- and post-urbanization scenarios, a substantial increase in runoff volume is observed for a 15-minute rainfall event with a five-year return period. Under pre-urbanization conditions, a runoff volume of 7,029 L was estimated, whereas in the post-urbanization scenario this value rises to 203,886 L, resulting in an excess volume of 196,857 L, equivalent to 196.86 m³, corresponding to an increase of 2,813 percent.

In view of this significant increase, and in alignment with the objectives of this study, it is proposed that this excess volume be stored in a detention basin with dimensions of 30 meters in length, 15 meters in width, and 0.44 meters in depth, as illustrated in Figure 8. The selection of its location near the outlet of the micro-watershed aims to maximize the capture of the generated surface runoff.

Table 5 – Parameters considered for the sizing of the detention basin.

Parameters	Values	
	Pre-urbanization scenario	Post-urbanization scenario
Event duration (t)	15 minutes	15 minutes
Return period (Tr)	5 years	5 years
Rainfall intensity (I)	107.25 mm/h	107.25 mm/h
Accumulated precipitation over the event duration (P)	26.81 mm	26.81 mm
Curve Number (CN)	71	88.47
Potential maximum soil retention (S)	103.75	33.10
Effective precipitation (P_eff)	0.33 mm	7.65 mm
Runoff coefficient (C)	0.01	0.29
Contributing area (A)	2.62 ha	2.62 ha
Peak discharge (Q_max)	7.81 L/s	226.54 L/s
Runoff volume (V)	7.029 L	203.886 L

Prepared by the authors (2025).

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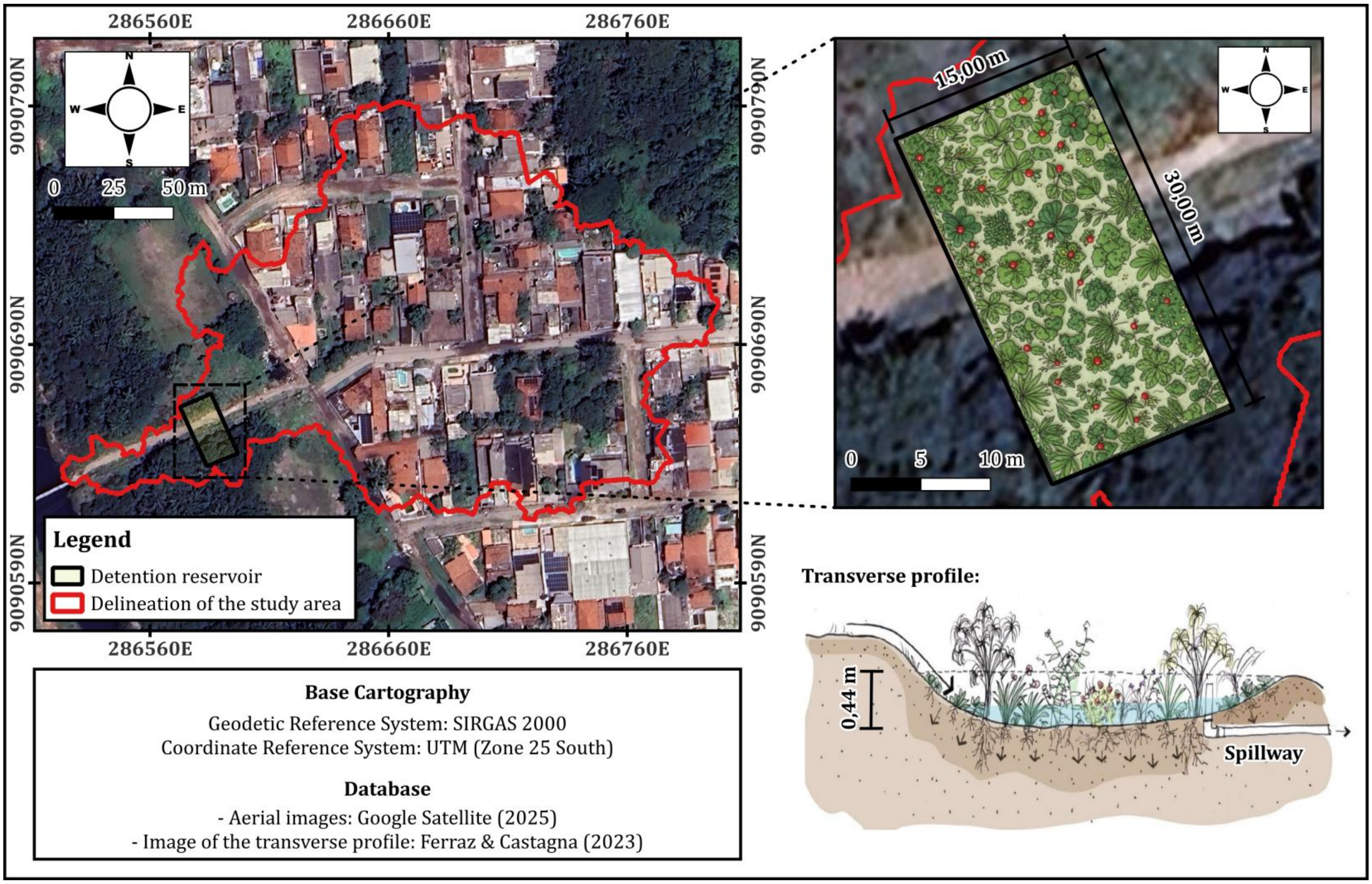

Figure 8 – Characteristics and location of the detention basin proposed in this study. (Prepared by the authors, 2025).

The excess runoff volume generated by urbanization has direct implications for stormwater management (Baltaci; Kalin, 2024). It is therefore essential to account for this additional volume when sizing detention reservoirs, whose function is to temporarily store excess water, thereby reducing peak discharge and mitigating the disturbances caused by flooding and urban waterlogging. Additionally, the implementation of a vegetated basin may provide complementary benefits, such as increased soil infiltration, improved water quality through the retention of sediments and pollutants, reduced surface runoff velocity, and enhanced landscape integration within the urban environment, contributing to broader environmental and ecological gains.

Considering the same study area, Pessoa Neto et al. (2023a) proposed the installation of detention reservoirs on each individual lot within the micro-watershed and found that, for a rainfall event with the same duration and return period adopted in the present study, the implementation of 45 basins would be required, totaling 87.06 m³. This practice is provided for in the Municipal Building Code of Jaboatão dos Guararapes, established by Law No. 973/2013, which defines the sizing criteria based on the reduction coefficient, the impervious area of the lot, and the regional rainfall index (Jaboatão dos Guararapes, 2013). However, this sizing model does not account for runoff generated from sidewalks, internal streets, and other impervious surfaces within the contributing watershed, which compromises overall system efficiency.

Similarly, Ferreira and Cabral (2025) developed an optimization model for sizing detention reservoirs in an urban watershed located in Recife, Pernambuco, aiming to reduce implementation costs and flooding risks. The authors defined the optimal characteristics for six detention reservoirs strategically distributed throughout the watershed to maximize retention and discharge control. The total inundated area was approximately 270,989 m^2, with maximum depths reaching up to 1.914 meters.

In a comparable study, Kempka et al. (2024) evaluated the impact of installing micro-resevoir in a residential development in a municipality in the interior of the state of Paraná. The authors conducted simulations for return periods of one, five, and ten years, identifying potential failures in the conventional drainage system. To mitigate the risk of urban waterlogging in the area, the adoption of this compensatory technique was proposed, resulting in a reduction of peak discharge of up to 47 percent.

These findings confirm the effectiveness of compensatory techniques in reducing the impacts caused by hydrological disasters and encourage public managers and decision-makers to develop policies that promote the implementation of such systems, particularly in areas undergoing urban expansion. It is important to emphasize that the selection of the most appropriate technique may vary depending on the urbanization pattern of the region, the watershed extent, the adopted return period, and other parameters deemed relevant to the study (Rodrigues; Santini Júnior, 2021).

V. FINAL CONSIDERATIONS

The present study aimed to propose the implementation of a detention basin as a compensatory technique in an area prone to flooding and urban waterlogging in the municipality of Jaboatão dos Guararapes, Pernambuco. The proposed technique was based on the excess surface runoff volume generated by the effects of urbanization within the study area, calculated as the difference between the total volumes produced under post- and pre-urbanization scenarios.

The results indicated that, with the implementation of the system, 196.86 m^3 of precipitation will be retained within the micro-watershed for a rainfall event lasting 15 minutes with a five-year return period. These findings demonstrate that the application of detention reservoirs is effective not only in reducing surface runoff but also in minimizing the disturbances caused by hydrological disasters in the region.

As a recommendation for future research, it is important to consider the concurrent implementation of additional compensatory techniques, such as rain gardens and linear parks, among others. These alternatives could enhance the positive effects of the proposed system and further contribute to sustainable stormwater management.

It should be noted that the results are conditioned by the limitations of the available data and the methodological simplifications adopted, as well as by the analytical scale restricted to the micro-watershed. This underscores the need for complementary studies that consider integration with the urban drainage system and empirical validation of the results.

Finally, the importance of conducting studies such as this one is emphasized, as they provide support for sound urban planning and offer innovative solutions for the development of sustainable cities, promoting the restoration of urban ecosystems and the mitigation of environmental impacts.

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